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ABSTRACT

The size, cost, and complexity of quantitative modeling in the social and physical sciences demand that modelers focus attention on premodeling phases of analysis, specifically on formulation and definition of problems. This is especially true in the areas of futures research and technology assessment. At the problem-defining stage of modeling, a key factor is communication among the modelers who classify and formulate the problems, and a computer-based communication system such as HUB could aid the problem-formulation process. The HUB system facilitates communication in four modes: PLANET conferences, shared visual spaces, program workspaces, and document workspaces. Benefits for users of such a system include: (1) more convenient and frequent communication among geographically distant model builders: (2) an opportunity to explore a greater variety of viewpoints on problems than might ordinarily be expressed due to constraints of time and distance: (3) the use of specific, already-designed techniques for searching out and generating problem definitions: (4) a greater concern for well-written text, concise expression, careful editing, and improved display of information: and (5) a more systematic, clear, and unambiguous articulation of positions that could increase the likelihood of translation, or mutual comprehension, among people looking at problems from different points of view. (AEA)

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AN INTERACTIVE COMPUTER-BASED APPROACH TO AID GROUP PROBLEM FORMULATION

By

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ABSTRACT

The size, cost, and complexity of quantitative modeling in the social and physical sciences demand that the modeler focus attention on premodeling phases of analysis, specifically on formulation and definition of "problems." This is especially true in the "softer" or less "well-structured" problem areas of futures research and technology assessment. At this stage of modeling, a key factor is *communication* among modelers. This paper briefly discusses approaches to classifying and formulating problems that illustrate the role of communication in modeling. It then describes a computer-based communication system as one possible aid in the problem-formulation process.

AN INTERACTIVE COMPUTER-BASED APPROACH
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THE PROBLEM WITH PROBLEMS

The types of problem situations we are currently attempting to model and the contexts in which such modeling activities are taking place have both undergone significant changes over the last decade.

Terms such as "problematique" and "mess" are now being used to describe complex problem settings. It is even suggested that the use of the term "problem solving" itself may be inappropriate. "Social planning has, however, come to be more like puzzle solving than problem solving. Each situation is so complex and unpredictable that one has to learn each unique set of steps that leads to a solution" (Emery, 1976).

More specifically, it has become quite apparent that people with different professional and personal perspectives within a group of model builders will have different ways of dealing with problems. Disagreements arise over the problem-solving techniques to be used, the relevant dimensions of a particular problem, and the criteria for classifying problem areas. Yet, beneath these disagreements over *how* to handle problems lie even more fundamental differences over *what* constitutes a problem in the first place. A problem to one person may very well be a nonproblem to another. The problem of "What is a problem?" is so subjective that, according to Tiege et al (1977:232), our only resort is simply to define a problem as "a condition which a group or an individual will decide is a problem."

CLASSES OF PROBLEMS

Numerous approaches to structuring problems have been developed (Beer, 1967; Simmonds, 1977; Mitroff and Kilmann, 1975). At a general level, a

one-dimensional scale has been suggested. Labels such as well-defined, ill-defined (Taylor, 1975) and hard, soft (Checkland, 1972) have been used to anchor the ends of the scale. The basic criterion for distinguishing between these two classes of problems is the existence or nonexistence of unambiguously defined operationally specified sets of objectives. "Well-defined problems are those for which there is essentially an agreement about ends and the general means for achieving them. The problem is typically that of choosing the 'best' among available alternatives. In contrast, ill-defined problems are those for which there is rarely agreement either about ends or means, and which, more often than not, cut across disciplinary boundaries" (Watson, 1978). As Checkland (1977) comments, the task of "soft" problem solving is "deciding what to do in the absence of a clear objective and an unequivocal measure of performance."

It is clear that well-defined problems are likely to be: technical or scientific; not overly complex; able to be unambiguously defined and measured; and capable of being discussed in a common well-specified language, without explicit reference to or concern with major changes in the problem environment.

Such problems, while important, only constitute a small component of real world problem solving. More likely, the problem facing modelers would have social and moral value considerations; be interpreted subjectively; be ambiguously defined; lack formally specified goals; prove a difficult domain in which to apply measurement; lack any single, acceptable, communication language; and be inexorably linked to a changing dynamic environment. Lipinski, Spangler, and Traweek (1978), for example, describe such a context in discussing macropolicy modeling. "Large scale policy models are usually developed by groups of five to seven people. Frequently, some of the model builders work in different locations around the country; they nearly always come from at least two or three different disciplinary backgrounds. The users of their models usually come from different organizations, with their own perspectives on problem solving ..."

What such "soft-problem" situations demonstrate is that there will always be multiple perspectives on any problem. And philosophically, each

viewpoint is valid in terms of its own assumptions. Thus, in the model building process, a range of different viewpoints must be taken into consideration in order to get a full picture of the problem--or nonproblem--at hand.

SOFT OR ILL-DEFINED PROBLEMS: THE NEED FOR COMMUNICATION

Approaches to "soft" problem formulation tend to focus on communication or communication-related activities. Within the context of corporate planning, for example, Ackoff (1970) introduces the concept of adaptive planning. "It (adaptive planning) is based on the belief that the principal value of planning does not lie in the plans that it produces, but in the process of producing them. In effect, the adaptive planner's slogan is, 'Process is our most important product.' Hence it holds that the value of planning to managers lies primarily in their participation in the process, not in their consumption of its product." This is supported by Emery (1974): "In a very real sense the most important product of this style of active adaptive planning is not the plan but the learning planning community--experts and laymen together. The process creates the conditions for learning to learn, affirms the overriding significance of shared ideals, and reduces the need for planning as a separate specialist organizational activity."

Checkland (1977) offers the same view in his discussion of problem formulation in "soft" systems analysis: "... we found that the 'soft' systems methodology which emerged from our research programs was not a methodology for finding efficient ways of achieving defined goals. Rather it was a methodology for serving a debate about the relative validities of a range of possible viewpoints."

Similarly, Mitroff (1977), in his discussion of problem formulation in the general area of technology assessment, suggests: "Instead of asking the question who should choose, the question how the choice should be made may actually be more important." In addition, Mitroff argues that problem solvers should be exposed to various perspectives on problem

formulation so that an "integrated-synthetic-comparative-analysis" may be possible.

Because the exchange of different viewpoints is so important in real world modeling, productive communication both among model builders and between model builders and model users is a necessity. This communication and coincident problem formulation begins at the premodeling stage. Perhaps the most crucial decisions involved in modeling take place at this point. Members of a modeling team decide what constitutes the problem, what their objectives are, what different perspectives on the problem can be identified, what structural units should be chosen to represent the problem area, and how those structural units are related. All this occurs before the actual construction of the model. Frequent communication during this premodeling stage sets the conditions and tone for communication throughout the modeling process.

One means of promoting this communication is to extend the electronic conferencing capabilities offered by the computer to the more task-focused applications required during the premodeling phase. We now outline a system designed at the Institute for the Future specifically to support these group problem-formulation activities.

THE HUB SYSTEM: A DESCRIPTION

The HUB system (Lipinski et al, 1979) is a computer-based group communication system developed for modeling applications in "soft" problem areas. It now resides in PDP-10 computers at Bolt, Beranek and Newman in Boston, the University of Southern California's Information Science Institute, and the University of Utah.

The HUB system facilitates communication in four modes: PLANET conferences, shared visual spaces*, program workspaces, and document workspaces, as shown in Figure 1.

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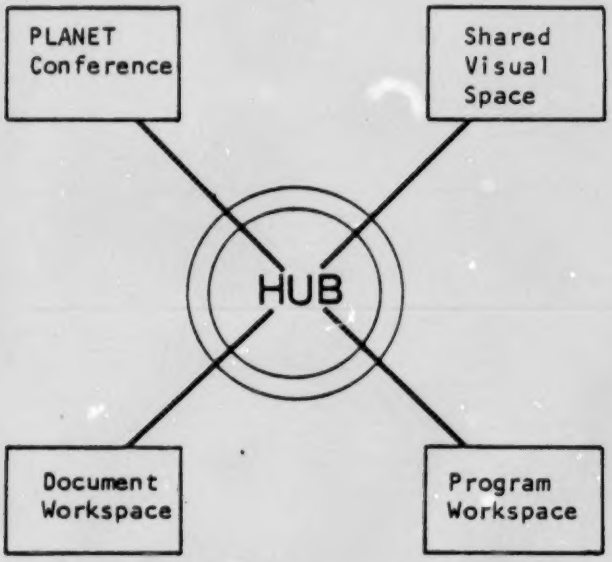
*not yet implemented

FIGURE 1
THE HUB SYSTEM



These four task-specific communication facilities are organized as separate modules in the HUB system, which is named for its central component, the "HUB." The HUB module itself is an intelligent switcher that makes it easy for users to access and move along the subsystems attached to it. In fact, we perceive the HUB system as a prototype for the management system of the future--a system in which a user can easily interact with a large number of computer-based resources. Once the user runs the HUB program, he or she has access to the following types of communication:

The PLANET Conference

A primary need of a modeling group, especially at the beginning of its efforts, is simply to discuss the project, its goals, the approach to be taken, the underlying assumptions, and known variables. Accordingly, we have included under HUB the PLANET computer conferencing system developed

at the Institute. PLANET provides this kind of open-ended communication. It allows the modeling team to "get together" without the time and travel constraints of face-to-face meetings; it also provides a complete transcript of the discussion. (PLANET as a communications medium has been extensively discussed in the Institute's publications.)

The Shared Visual Space

As the form of the model begins to emerge from initial discussions, a block diagram or flow chart can be useful in representing it. Graphical representation of the output from the model can also help the modeling team. Just as PLANET is oriented toward the exchange of text, the shared visual space is a subsystem oriented toward graphic communication. Using it, modelers will be able to create, view, exchange, and modify a wide variety of graphic images, including block diagrams, flow charts, bar charts, graphs, and, to some extent, sketches. Comments can be attached to the various parts of images, providing "on-the-spot" explanations of particular items or of changes that have been made.

We hope to implement the shared visual space by early 1980. When complete, this software will support a range of terminals, from those with sophisticated graphics capabilities to simple paper-printing teletypes.

The Program Workspace

Building a computer model includes the use of existing computer programs as well as the development of new programs. The program workspace is designed to aid in these two activities.

When a user enters the workspace and begins to run a program (either on the same or a remote computer), others may join him or her in a kind of "looking-over-the-shoulder" mode. While any number of onlookers can join and participate in the discussion, only one user effects changes in the program. All users will see the entire transcript of the program run on their own terminals; they can also exchange comments about the run as it proceeds. For example, if the program is a piece of the model, they might debate the values to be supplied for the model's parameters. The transcript

of these "synchronous" runs (including comments) can be stored for later users who were not present. This capability can facilitate joint development of programs, but equally important will be the ability to use a variety of existing computer-based premodeling tools.

The Document Workspace

If the model's goals and assumptions are to be made clear, if users are going to be able to maintain the model, and if it is to serve the needs of the model users, then documentation is essential.

The HUB system as described so far aids documentation in several ways. The discussions, explanations, and transcripts of program runs are all saved and can be reviewed later in a structured manner. The document workspace focuses on another aspect of the problem: the preparation of the modeling project's "formal" documents. In this subsystem, documents can be prepared, reviewed, and edited using a simple, line-oriented text editor. Furthermore, users can hold a PLANET-like discussion about the documents in order to make comments or criticisms.

One important note: our discussion of the other subsystems has been roughly "chronological." Most modeling projects will proceed from general discussion, to graphic representation, to a computer program. The document workspace breaks this progression, since an effective modeling team will produce documents throughout the modeling effort.

THE HUB SYSTEM: ITS ROLE IN PROBLEM FORMULATION

Group contribution and communication is an essential aspect of the task of problem formulation. All four HUB modules can be used to facilitate the particular types of communication involved in problem definition. The conferencing system, PLANET, gives both model users and model builders the opportunity to discuss and mutually define problems before a model is actually constructed. The program workspace allows modelers to run modeling programs, access data bases, run other types of programs such as structural modeling packages, comment on these program runs as they occur,

and show them to the other participants. The document workspace permits the group to document essential assumptions as they are defined. And the shared visual space is intended to provide visual tools to assist in conceptualizing a problem. A transcript recording the entire conference is always stored in the HUB system and available to any participant.

Because the HUB system is designed to facilitate communication within a group working on a joint task, it is both similar to and different from other computer-based communication systems. The Electronic Information Exchange System (EIES) developed at the New Jersey Institute of Technology provides a user with a number of services: messaging, conferencing, bulletin boards, personal notebooks, and word processing (Hiltz and Turoff, 1978). The CONFER system of the University of Michigan offers conferencing within a general purpose facility that may be used for data analysis, modeling, and other computing (Zinn, 1977).

In contrast, the HUB system is oriented toward the accomplishment of very specific modeling tasks rather than the provision of many diverse communication services. The design of HUB was focused around several specific questions:

- What computer-based communication facilities are needed to support the modeling process?
- How might they best be structured to promote communication through the display of information, group interaction, and storage of information?
- What aspects of the modeling process are most suited to computer-based communication support?
- What types of computer-based resources are necessary to allow a group to interact effectively?

Field tests conducted so far indicate a variety of ways in which the HUB system can encourage task-related communication of geographically separated individuals. For example, one user group consisted of members of five corporations in different parts of the country and three representatives of the Institute for the Future. All participated in an Institute-organized conference on factors affecting international trade during the next decade. Participants were selected on the basis of their interest and expertise in this area. The conferencing facility of HUB was used to train corporate participants to run the HUB system, to delineate

relevent variables, to review and comment on forecasts, and finally to construct scenarios using a forecasting program set in the program workspace. The conference was scheduled for specific times over a three-day period, with communication being primarily synchronous (i.e., all participants were online at the same time).

Another group used the conferencing module to bring together geographically distant individuals who wished to contribute to the translation of a computer modeling language. Communication was asynchronous; i.e., participants were not online at the same time, but entered messages at their own convenience. This asynchronous style did not in any way diminish the sense of "group" communication.

Problem formulation and definition require the analyst to build the richest possible picture of the problem situation. Although it is recognized that the final model will never be complete, "in judging the usefulness of a model, one crucial issue is whether the 'important' variables and the important relationships among them are being represented" (Linstone, 1978).

HUB can accommodate specific techniques of problem formulation. Those techniques useful in "soft" problem areas have been summarized by Linstone (1978). They cluster into two classes:

- those which focus on the scanning, search, generation, or identification of problem dimensions; and
- those which are concerned with structuring and patterning, i.e., exploring and defining the relevant patterns and relationships between components.

Both these classes of techniques can be adapted for use within a computer-based communication system.

SEARCHING AND GENERATING TOOLS

Various procedures have been suggested for generating problems or, more specifically, generating the relevant issues that constitute the problem space. These include group brainstorming and lateral thinking (de Bono, 1970, 1971), nominal group technique (Delbecq et al, 1975), and the search conference (Emery, 1976).

A recent summary (Lendaris, 1978) of techniques for generating the relevant issues and variables within problems classified more than 20 methods into two categories:

1. Those emphasizing an atmosphere for free-wheeling thinking (brainstorming, nominal group techniques).

2. Those emphasizing structured guidance for carrying out the design/solution activities.

This latter category is further subdivided into:

a. Methods using words as the vehicle for the structured guidance (morphological analysis, attribute analysis, function analysis, misfit variable concept).

b. Methods using a geometric figure and/or analysis techniques as the vehicle (trees, networks, and pattern recognition).

A computer conferencing system such as PLANET will certainly accommodate Category 1 techniques encouraging unstructured and creative group thinking. With the addition of the program workspace, the HUB design also allows the inclusion of the formal techniques of Category 2. For example, a morphological structure or a network analysis may be included either as a package or as a set of decision rules in the search or generation exercise.

As part of our testing of the HUB system, we have found that the use of this new communication system can lead to changes in problem structuring. While users may find it comfortable to think while they talk, they do not find it comfortable to think while they type and work on a terminal. They think first, formulate their point, and then send the message. One user commented that the computer-based medium is satisfactory only when you already know what you want to say. Given this need for thinking time,

users always seem to prefer asynchronous rather than synchronous communication in HUB. The asynchronous mode avoids long waiting periods between messages and allows for well-formulated thinking. Consequently, problem formulation in a computer environment like HUB may consist of better thought out viewpoints and more precise arguments than problem formulation in an ordinary face-to-face session.

Group dynamics also take a particular form in the context of HUB. In a conference, subgroups concerned with specific issues may develop. When a subgroup works on a particular problem, the entire group can monitor the discussion. If problem formulation were taking place in a face-to-face session, these subgroup activities would very likely be kept private. In HUB, the forum remains open.

STRUCTURING RELATIONSHIPS

Once a set of issues has been identified, the focus of premodeling switches from problem formulation to patterning or structuring. The output of this stage may range from a better appreciation of the relevant variables to a first approximation to a model. Clearly these tasks of search and structure may be undertaken concurrently and interactively.

Structural modeling is the exploration and definition of patterns of relationship among components in a system. Structural models tend to be geometric rather than algebraic and stress form and structure over quantitative output. An example is the computer-aided technique (developed by Warfield, 1973) known as Interpretive Structural Modeling (ISM), designed to allow small groups to quickly develop a "first-cut" structural model. A more general set of tools has been amassed in the SPIN package. This is a user-oriented, interactive computer program which includes interaction matrices, directed graphs, causal-loop diagrams, feedback loop analysis, pulse analysis, matrix powering, and clustering (Curnow et al, 1976).

Linstone et al (1978) have recently completed a comprehensive review and evaluation of structural modeling tools for technology assessment. In addition to ISM and SPIN, they suggest that *ELECTRE* (Roy, 1971), IMPACT

(O'Leary, 1975), KSIM (Kane, 1972), and QSIM (Wakeland, 1976) all have potential for use by problem analysts in this phase of problem formulation.

Such techniques could form the core of a library of premodeling tools that would be usable through the HUB system. As a first step toward developing such a library, the KSIM package has been modified and implemented for use with HUB. KSIM is a readily accessible, preprogrammed computer algorithm. It uses a single methodological framework--cross-impact analysis--to approximate the real world behavior of the system being studied. It is intended primarily for use by policy analysts and decision makers.

A simulation technique, KSIM can be used to explore both subjective, intuitive concepts and quantified or mathematically-defined relationships. Thus, it differs from other simulation packages designed to cope solely with "hard" systems that have deterministic relationships based on known data. This difference is significant, as it is often the subjective (and consequently ignored) variables and interactions that are the controlling parameters of political, social, and socio-technical systems.

In the corporate field trial identifying factors affecting the level of international trade, the KSIM program was used to provide compatible forecasts and to explore possible scenarios. Critical variables and their interrelationships were identified, and their impact on the level of international trade assessed. The output was available for comment by all members of the problem team, and sensitivity runs were specified by various participants.

By providing access to KSIM and other premodeling tools, the HUB system could make a significant contribution to the early stages of model building. With such tools, a modeling team could test several alternative structures before committing itself to any type of mathematical model.

CONCLUSION

In this paper, we have suggested some likely effects of using a computer-based communication system, HUB, in problem formulation. The use of a computer-based system may allow more convenient and frequent communication among geographically distant model builders and users. It may provide an opportunity to explore a greater variety of viewpoints on problems than might ordinarily be expressed due to constraints of time and distance. It may encourage the use of specific, already designed techniques for searching out and generating problem definitions and for structuring and patterning problem areas.

Yet the incorporation of a new communication system is bound to bring about changes in the problem formulation process. As our field tests have suggested, the computer-based medium in which all communication occurs in written form and becomes available to an entire group seems to make people feel that they must present more carefully thought out and precise contributions than in ordinary face-to-face sessions.

Lederberg (1978) has already suggested that computer-based communication can actually foster a "new literacy." A greater concern develops for well-written text, concise expression, careful editing, and improved display of information. With respect to problem formulation, a more systematic, clear, and unambiguous articulation of positions would perhaps increase the likelihood of translation, or mutual comprehension, among people looking at problems from different points of view. Such an improvement in communication seems especially desirable in those "soft" situations where problems are open to the subtle shades and distinctions of interpretation.

Whatever its virtues, however, any new communication system is apt to be accepted only hesitantly. Reading, writing, and typing are slow and sometimes seen as beneath the dignity of professionals. Costs often prohibit the immediate adoption of a new medium. Thus the positive effects of using a system like HUB in problem formulation may be slow in developing. And negative repercussions may occur as well. Greater participation and an increase in the variety of perspectives presented may result in

confusion rather than clarification. The politics of group problem formulation may thrive on this confusion, as particular group members find misunderstanding more useful than understanding in fostering their own special interests. Similarly, the problems involved in establishing the authorship of a particularly significant idea may inhibit open expression.

Despite these reservations, however, the need for communication in problem formulation is clearly evident. The "soft" problems of large-scale modeling involve a variety of factors--social, political, and attitudinal as well as economic and technical. The nature and interrelationships of these variables are changing and uncertain. The difficulty of the problems themselves is reflected in the difficulty of the problem formulation process. Communication, admitting multiple perspectives on multiple variables, becomes even more essential. With the introduction of a computer-based communication aid such as HUB, we can create a new modeling environment responsive to the needs of complex, real world modeling problems.

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